Auroville Earth Institute
UNESCO CHAIR EARTHEN ARCHITECTURE

# POURED EARTH CONCRETE (PEC) RESEARCH

## ROAD EXPERIMENTATION AT VISITOR'S CENTRE MARCH 2015

### REPORT, JULY 2015

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# ACKNOWLEDGEMENT

Our gratitude goes first to Nicole and Peter who wished to do the experiment of an actual road for the Auroville Visitor's Centre with the new technique developed by the Auroville Earth Institute.

Our thanks also go to the Auroville Road Service who gave their assistance with the delivery of equipment and materials and machinery for making the road.

Thanks also to the Matrimandir team who provided the bobcat for levelling the road and supplying the earth.

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# 1. INTRODUCTION

## 1.1 FOREWORD

The technique of Poured Earth Concrete (PEC) is a new field of research which was begun in 2011 by the Auroville Earth Institute (AVEI).

This report documents the experiment of the PEC road done at the Auroville Visitor's Centre in March 2015. This new road was a development of the experiments cast in August and December 2014 at AVEI premises.

## 1.2 SUMMARY OF PREVIOUS RESULTS AND AIM OF THE NEW EXPERIMENT

Poured Earth Concrete has been used successfully at AVEI to cast wall samples of various lengths. The experiment of casting roads aimed to check how to optimise a mix while to prevent shrinkage, have good workability, appropriate strength and resistance to abrasion.

**Results of road at AVEI in August 2014**

This first road experiment gave very satisfactory results. This road portion was relatively small (~36 $m^2$: 7.4 m long x 4.85 m wide average). The mix used for this experiment was relatively dry: Most of the slump tests varied from 13 to 26 mm with a minimum at 9 mm and a maximum of 42 mm, giving an average of 24 mm. Thus the workability of the mix was difficult. This road did not develop any cracks until the very hot season of 2015. Since March 2015, a very few small hair cracks developed when temperature rose above 35° C.

**Results of road at AVEI in December 2014**

When the second road was cast in December 2014, the first one cast in August 2014 had not yet developped any cracks. Therefore the mix ratio for the experiment of Dec. 2014 was done based on similar proportions as the one of Aug. 2014. More water was added to test workability and shrinkage behaviour and the aim of the road of Dec. was to explore how a longer, continuous road section would behave without split joints. The mix for this road had a little more soil, with 39.07% instead of 36.69% in August. This road had an area of 102 $m^2$ with a maximum length of 15.86 m. Workability was improved due to the addition of water. A few shrinkage cracks developed 2 months after casting and they widened with 2-3 mm in some parts during the hot season of 2015. Today, 1 month after that the road at the Visitor's Centre has been cast, the road of December at AVEI developed many more small and short hair cracks, due to the excessive temperature: the air temperature under shade is 36-37° C but the surface temperature has been recorded at ~60° C.

**Aim for the road at the Visitor's Centre of March 2015**

The main aim of this road was to explore how to make a road with the actual section of a road, with proper curbs, slope, embankment, and to determine how to make split joints, with continuous casting. Other aims were:

1. To check the workability of the PEC with a modified mix
2. To improve the working process which was developed earlier
3. To observe if cracks would develop on road sections varying from 39 to 53 $m^2$ (with maximum length of 9.36 m)
4. Observe the durability of the road, where all vehicles access the site

## 1.3 TRAFFIC

The roads cast at the Visitor's Centre has a medium daily traffic of ~50 motorbikes, ~100 cars, ~20 vans and buses. During the peak season of visitors, the traffic can increase up to 500 vehicles a day. The speed of these vehicles is low and ranges from ~10 to 30 Km/h.

# 2. ROAD DETAILS

## 2.1 ROAD DIMENSIONS, LAYOUT AND SECTION

This road is the access to the parking of the visitors. It had an area of 210 $m^2$ with varying width of 6.5 m on one side and of 4.5 m on the other side. The road has been divided into 5 sections: two of 39 $m^2$, and three others of 37.8, 41.7 and 53.2 $m^2$. This division was for the purpose of limiting the length of the sections to ~9 m.

The sub-course was planned to be with a thickness of 10 cm, and the wearing course of 15 cm thick. The slope of the road followed approximately the existing level of the site, which had already a slope similar to that of the road.

The geometry of the existing access was such that the site had to be excavated with a JCB only at both ends of the site. This saved a lot of time for the work. See Fig. 2 Site layout and construction sequences (next page). Only certain areas had to be levelled by hand to laying the curbs.

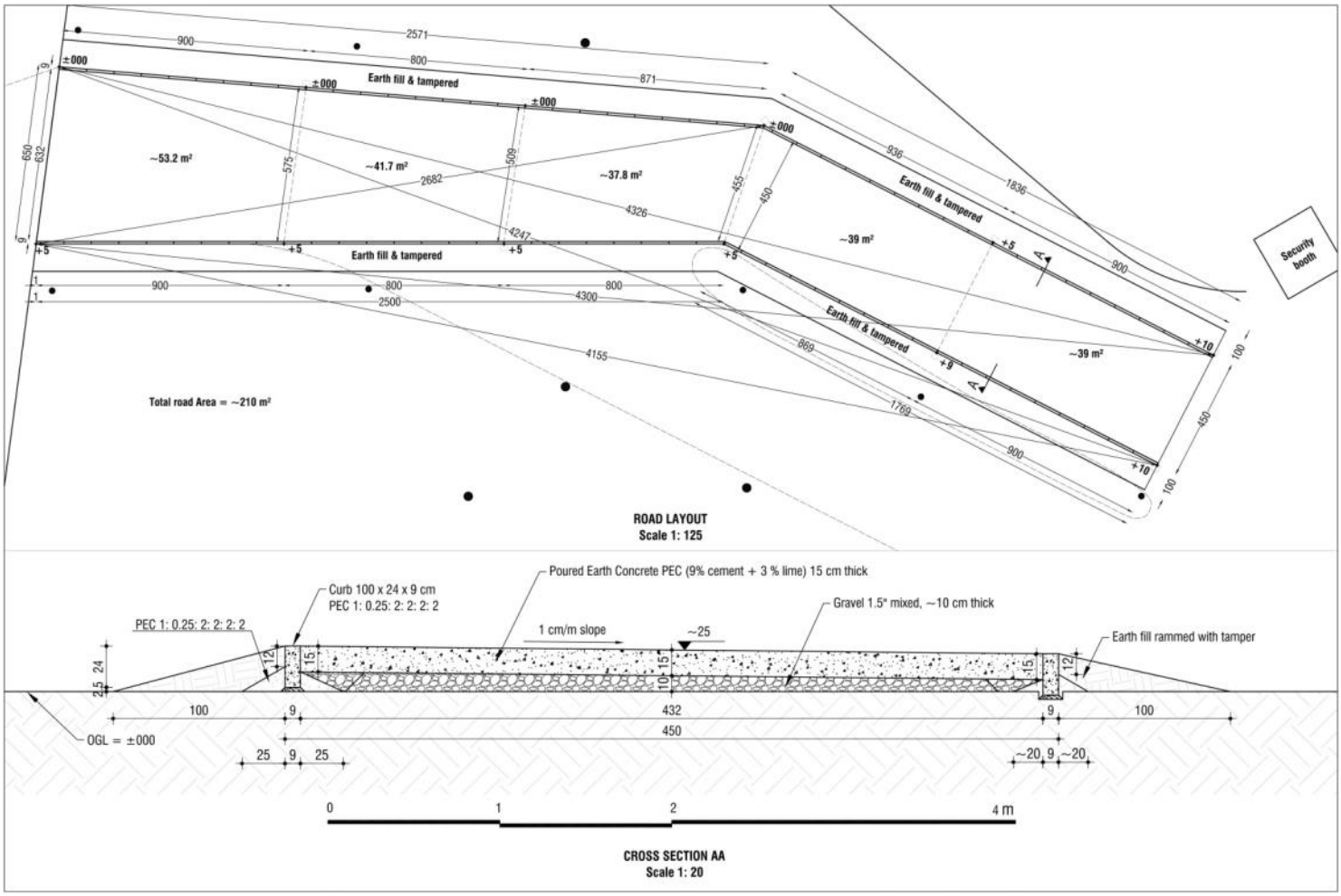



*Fig. 1: Road plan and section*

## 2.2 SITE LAYOUT AND GENERAL ORGANISATION

The site was organised with all materials stacked on the side of the road, to minimize transport during casting. The soil was crushed on the south side of the road and was moved later on the side of the road with a bobcat. The site organisation sequence was as such:

1. Site preparation and marking levels
2. Delivery of aggregates on the side of the road and delivery of the soil near the crusher.
3. Delivery of curbs on both sides, along the road.
4. Excavation with a JCB at both ends on the side. A ramp was kept initially on the west side for allowing access to trucks. This ramp was dug by hand, once all deliveries were completed.
5. Crushing soil on the south side. Moving the crushed soil with a bobcat to the side of the road.
6. Laying the curbs.
7. Filling the embankment outside of the curbs with red soil (by hand) and tamping it.
8. Delivery on the road of gravel 1.5" mixed for sub course.
9. Levelling gravel on the road with a bobcat.
10. Rolling the sub course with the roller compressor.
11. Finalising by hand the sub course on the inner sides of the curbs and rolling with the roller compressor.
12. Casting concrete starting from East side (near security gate).

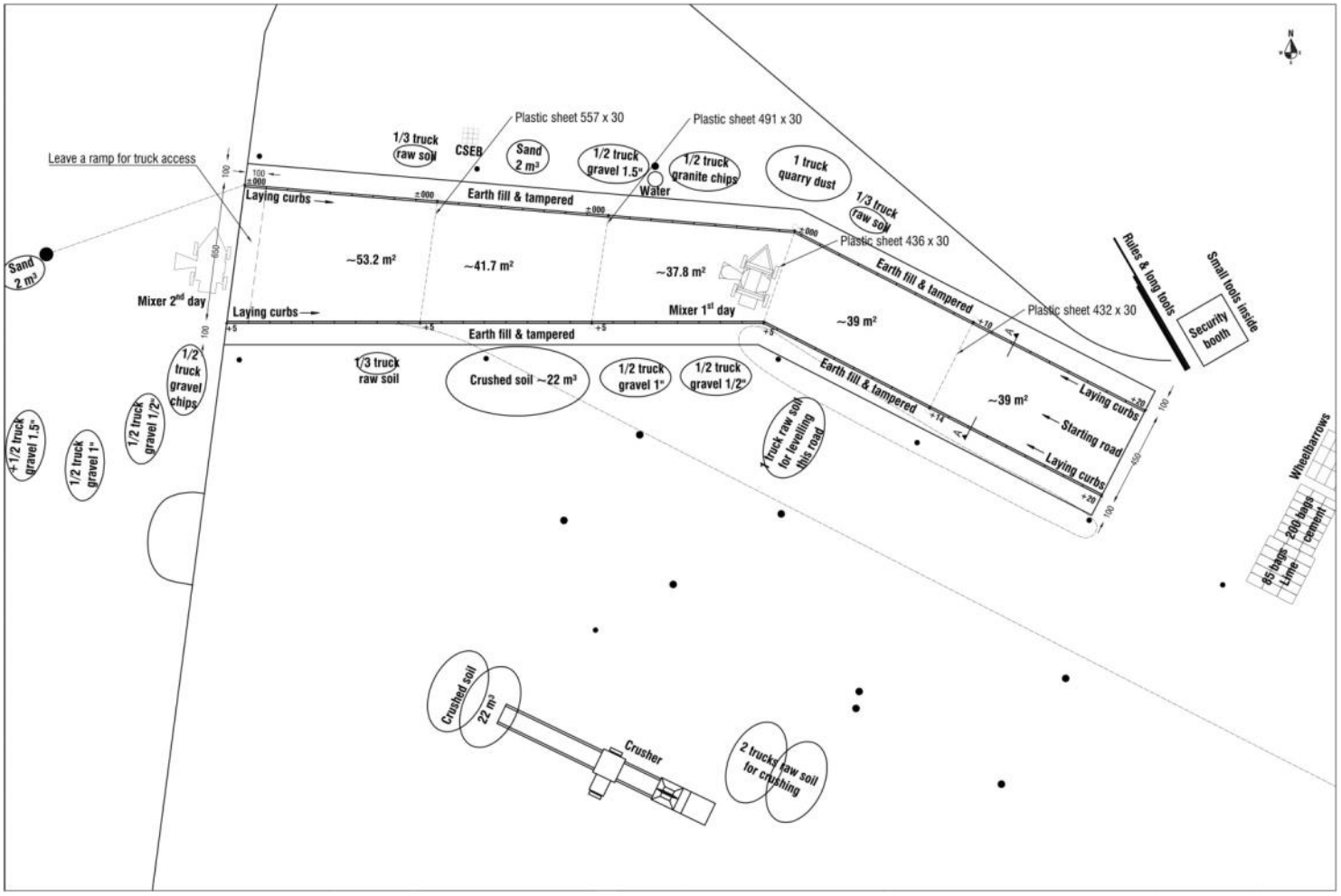



*Fig. 2: Site layout and construction sequences*

## 2.3 CONSTRUCTION SEQUENCE

After excavation with the JCB and delivery of all materials, the construction sequence of the road was as such:

1. Marking the levels for laying the curbs:
   Some mortar (cement, sand CSM 1: 5) was laid on the ground to mark the bottom level of the curb.
   Elsewhere, the ground was dug by hand wherever needed and some mortar was also used to mark the level.
2. Laying the curbs (starting from both extremities)

   Curbs were laid on 1 cm thick mortar CSM 1: 5
   Note that no mortar was laid in the vertical joint of the curbs: they touched each other.
   Once curbs were laid, some PEC was cast on either side to hold them in position.
   The mix for this PEC was the same as that for precasting the curbs:
   $PEC_{curb}$: 1 cement: 0.25 lime: 2 soil: 2 sand or QD: 2 gravel 1/2": 2 gravel 1"
3. Unloading of 4 trucks of 1.5" mixed gravel in the centre of the road
4. Filling manually the embankment, outside of the curbs with red soil
5. Tampering the red soil filling of the embankment with the road tamper and with hand rammers
6. Levelling 1.5" mixed gravel of the sub course with a bobcat and finalising it by hands on the sides
7. Rolling the sub course with the roller compressor from the Road Service
8. Casting concrete starting from East side (near security gate)

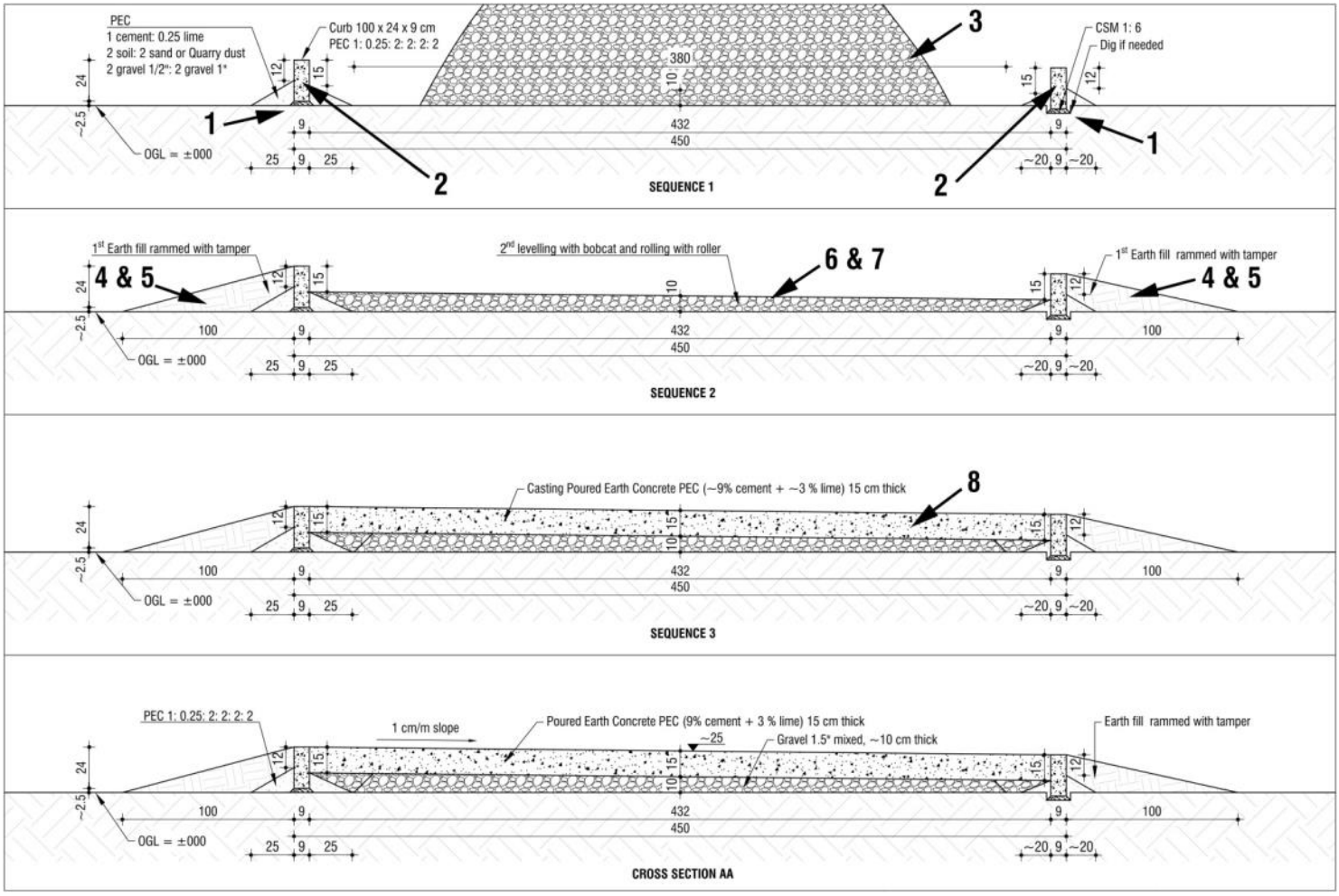



*Fig. 3: Construction sequences of the road*

# 3. MATERIALS AND MIX PROPORTIONS

## 3.1 MATERIAL CHARACTERISTICS

### 3.1.1 Soil

The soil for this road came from the old remaining pile of the excavation of Matrimandir. It was composed of layers of different soil qualities, as it was moved many times. As it was laying there for more than 45 years, vegetation had grown on the pile and the soil was full of roots. Big roots were removed before crushing the soil, but smaller roots often clogged the crusher. Sensitive analysis was conducted on the crushed soil and it was found to be clayey silt with the following proportions.

This soil was much more clayey and silty that the ones used on roads at AVEI premises. Thus, during casting it tended to crack more than the other ones and this is why sand was added in the second mix for the road. See paragraph "3.3 Mix ratios for casting the road" (next page).

| Gravel | Sand | Silt | Clay |
|---|---|---|---|
| 0 % | 30 % | 40 % | 30 % |

*Table 1: Proportions of crushed soil (Sensitive tests results)*

### 3.1.2 Bulk densities

The densities given here are the average bulk densities measured from 3 samples. The density of soil has been measured on the weight of 50 L. of soil which was filled in the wheelbarrows. The densities of aggregates were measured on materials filled in boxes of 42 litres, which were shaken before measurement.

| Cement | Lime | Crushed soil | Sand or QD 2 mm | Gravel Chips | Gravel ½" | Gravel 1" | Gravel 1.5" | Water |
|---|---|---|---|---|---|---|---|---|
| 1.2083 | 0.6462 | 1.3995 | 1.5257 | 1.3393 | 1.3885 | 1.4528 | 1.3977 | 1 |

*Table 2: Bulk densities of materials*

For later experiments, it would be better to follow the same protocol to measure the density of all samples: by measuring the weight of materials filled in the various volumes. This would give a more acurate bulk density of materials filled in the mixer.

## 3.2 MIX RATIO FOR PRECASTING CURBS

Curbs were precast with a different mix ratio. They had a little more cement stabilisation (9.6%), as the edges could have more stress if a vehicle would drive on them to go on the embankment. The mix ratio of soil/aggregates was also different with equal parts of all components. Slump test for this mix was 33 mm.

| Item | Measurement | % by weight | Container details |
|---|---|---|---|
| Cement | 50 Kg | 9.60 | 1 bag |
| Lime | 10 Kg | 2.08 | ¼ Bag filled partially in a box of 42 L. |
| Crushed soil | 80 L. | 25.44 | 1 Wheelbarrow 50 L. + 2 buckets 15 L. |
| Sieved sand 4 mm | 80 L. | 25.72 | 1 Wheelbarrow 50 L. + 2 buckets 15 L. |
| Gravel chips | 80 L. | 24.62 | 1 Wheelbarrow 50 L. + 2 buckets 15 L. |
| Gravel ½" | 80 L. | 24.22 | 1 Wheelbarrow 50 L. + 2 buckets 15 L. |
| Water (main casting) | ~55 L. | 10.36 | (2 Buckets 22 L. - 4 L.) + (1 bucket 15 L.) |

*Table 3: Practical mix ratio for precasting curbs*

## 3.3 MIX RATIOS FOR CASTING THE ROAD

Three mix ratios were done for the road of the Visitor's Centre. The initial mix was slightly modified from the mix ratio of the road cast in December 2014 at AVEI premises. The main modification was the increase of gravel chips, for more resistance to abrasion, with 75 L. for the Visitor's Centre instead of 50 L. in December. More cement was also initially added in March, with 8.634 % instead of 7.999 % in December.

However this mix ratio was difficult to work with as there was too much gravel chips: the screed ruler was pulling too much gravel, leaving a honey comb in the PEC surface. About half of the first section of 39 $m^2$ was done with the following mix, table 4, and then the mix was changed for the second mix ratio shown in table 5.

| FIRST MIX RATIO | Cement | Lime | Crushed soil | Coarse Sand | Gravel Chips | Gravel ½" | Gravel 1" | Gravel 1.5" | Water |
|---|---|---|---|---|---|---|---|---|---|
| **Practical mix (1) March 2015** | 40 Kg | 15 Kg | 100 L. | - | 75 L. | 50 L. | 30 L. | 50 L. | ~55 L. |
| **Practical % (1) in March 2015** | 8.634 | 3.422 | 33.062 | - | 23.730 | 16.401 | 10.296 | 16.510 | 11.499 |

*Table 4: First mix ratio*

The second mix was modified by reducing the amount of gravel chips: 50 L. were added instead of 75 L. More 1" gravel was added: 50 L. for the second mix instead of 30 L. for the first mix. Therefore the modification of the proportions of gravel changed the percentage of stabilisers, with a slight increase from 8.634% to 8.717% of cement and 3.422% to 3.457% of lime. This second mix was used only for the 2nd half of the first section, as during lunch time the first portion of the road cast with the first mix started to crack due to direct sun on the road.

| SECOND MIX RATIO | Cement | Lime | Crushed soil | Coarse Sand | Gravel Chips | Gravel ½" | Gravel 1" | Gravel 1.5" | Water |
|---|---|---|---|---|---|---|---|---|---|
| **Practical mix (2) March 2015** | 40 Kg | 15 Kg | 100 L. | - | 50 L. | 50 L. | 50 L. | 50 L. | ~55 L. |
| **Practical % (2) in March 2015** | 8.717 | 3.457 | 33.412 | - | 15.987 | 16.575 | 17.342 | 16.684 | 11.607 |

*Table 5: Second mix ratio*

The third and last mix attempted to correct the problem of shrinkage due to direct sun on the first part. The soil was reduced from 100 L. to 75 L. and 25 L. of coarse sand was added to the mix. Gravel chips were again increased to 60 L. to possibly reduce shrinkage. This resulted in a final proportion of 24.106% of soil instead of 33.062% for the first mix. The amount of cement was slightly reduced, so as to be closer to the percentage used for the road in December: 8.027% of cement and 3.330% of lime were the final mix for the last three sections of the road. This mix was used from the 2nd till the final section of the road.

| THIRD MIX RATIO | Cement | Lime | Crushed soil | Coarse Sand | Gravel Chips | Gravel ½" | Gravel 1" | Gravel 1.5" | Water |
|---|---|---|---|---|---|---|---|---|---|
| **Practical mix (3) March 2015** | 38 Kg | 15 Kg | 75 L. | 25 L. | 60 L. | 50 L. | 50 L. | 50 L. | ~56 L. |
| **Practical % (3) in March 2015** | 8.027 | 3.330 | 24.106 | 8.760 | 18.456 | 15.945 | 16.683 | 16.050 | 11.466 |

*Table 6: Third mix ratio*

The problem of initial shrinkage, which did not occur for the road of Dec. 2014 at AVEI premises, was due to the following factors: Firstly, the direct sun on the road evaporated the mix too quickly. The air temperature under shade at noon was 35 °C but the surface temperature of the ground was 50 °C. Second, the soil used in March was from Matrimandir and was more silty than the soil of December.
The first section of the road started to crack during lunch time, about 2 hours after casting. Cracks were repaired by filling in a little water and by closing them while pressing with a trowel. One month after the road was cast these cracks opened again and had only the size of hair cracks. A transversal crack developed also one month after casting on half the width of the road in the middle of the second section of the road.

**Notes for percentage by weight**

- Cement and lime are calculated on the dry weight of the total mix.
- Soil and aggregates are calculated on their dry weight only (without weight of stabiliser and water).
- Water is calculated on the total weight of the dry components (cement, lime, soil and aggregates).
- Percentages are calculated with the bulk densities given in paragraph "3.1.2 Bulk densities".

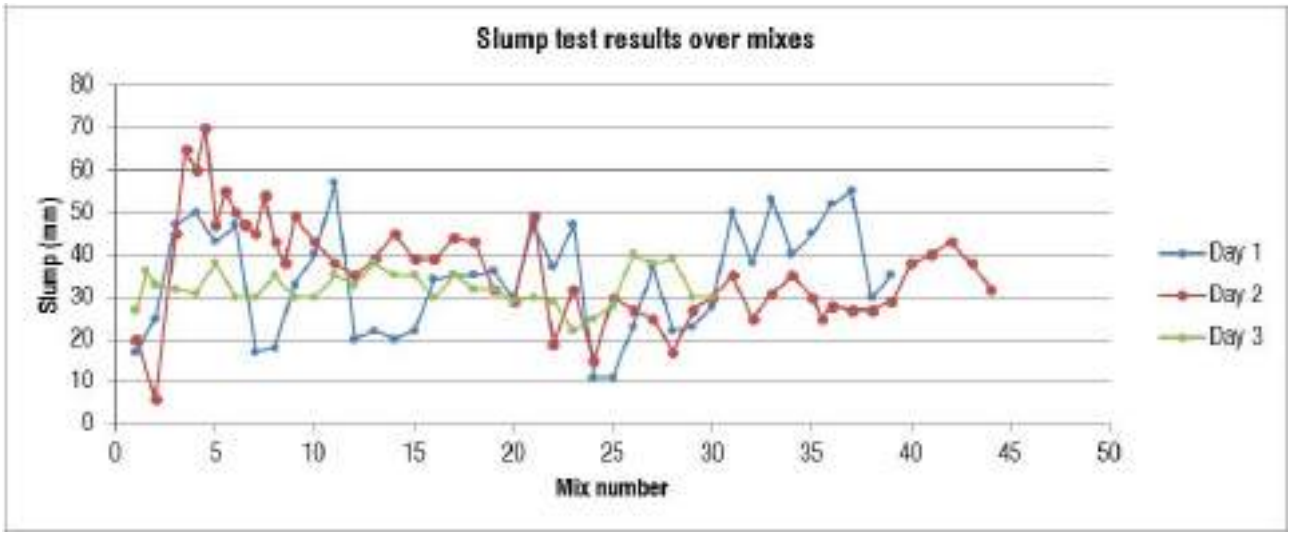
| Item | Measurement | % by weight | Container details |
|---|---|---|---|
| Cement | 38 Kg | 8.027 | 1 bag – 12 Kg (which are poured in a box of 42 L.) |
| Lime | 15 Kg | 3.330 | Box of 42 L. (partially filled) |
| Crushed soil | 75 L. | 24.106 | 1 Wheelbarrows 75 L. |
| Coarse sand | 25 L. | 8.760 | 1 bucket 15 L. + 1 bucket 10 L. |
| Gravel chips | 60 L. | 18.456 | 1 Wheelbarrow 50 L. + 1 bucket 10 L. |
| Gravel ½" | 50 L. | 15.945 | 1 Wheelbarrow 50 L. |
| Gravel 1" | 50 L. | 16.683 | 1 Wheelbarrow 50 L. |
| Gravel 1.5" | 50 L. | 16.050 | 1 Wheelbarrow 50 L. |
| Water (main casting) | ~56 L. | 11.466 | (2 Buckets 22 L. - 3 L.) + (1 bucket 15 L.) |

*Table 7: Practical and final mix ratio for casting the road*

## 3.4 WATER CONTENT AND SLUMP TEST FOR CASTING THE ROAD

Two students were in charge of recording the values of slump test for every mix. The aims of these tests were to control the influence of the water content on the workability, to define the ideal amount of water and to control the homogeneity from mix to mix.

Graph 1 shows a lot of variations in the slump test, especially in the first and second day, which was the worst, with variations from 6 to 70 mm. The third day was better, as batches were more homogeneous and the average slump test was 33 mm.




*Graph 1: Slump test distribution per day*

There were a lot of trials for the water content during the first day, so as the get the proper moisture content for a good workability. Water content varied between 59 Litres and 55 Litres. Hence the first variations were due to the varying amount of water. After some time a proper the slump test was found to be around 33 mm with 56 L. of water.

This important variation of these slump tests can be mostly explained by the fact that the sampling by the students for the slump test was not done rigorously and because the mix in the drum was not homogeneous. Typically, the mix in the front part of the drum was drier than the part in the back side. Therefore students were apparently taking samples randomly either from the front side of the drum (drier), which was dropped into the first wheelbarrow, or from the last part of the mix (wetter), which was dropped into the second wheelbarrow.

This implies that for future roads:
1. More attention should be paid to have a more homogeneous mix in the drum.
2. Sampling of the PEC should be done more evenly on a more homogenous sample.

# 4. WORK DETAILS

## 4.1 TEAM DETAILS

### 4.1.1 Number of workers per work

The following set of tables give the details of workers per day and per work. These are the actual number of people who worked on this road. The number of workers is expressed in "man/day". If a worker is mentioned with a fraction, it means the fraction of a day (i.e. 1 day with 0.25 man/day = quarter day = 2 hours).

Note that several works were occuring at the same time and often the supervisor was supervising several jobs. The following tables do not include the details of the drivers of trucks and small carriers who delivered materials.

| PRECASTING 90 CURBS | | | | |
|---|---|---|---|---|
| **Task** | **Days** | **Man/day** | **Skill** | **Details** |
| **Supervision** | 3 | 0.25 | Supervisor | Checking mixes, casting and slump test |
| **Masonry** | | 1 | Mason | Preparation of formworks and casting |
| **Handling** | | 2 | Worker | Mixing poured earth concrete and helping the mason |
| **Total** | **3 days = 1 supervisor (2 hours/day), 1 mason, 2 workers** | | | |

| TOOLS AND SITE PREPARATION | | | | |
|---|---|---|---|---|
| **Task** | **Days** | **Man/day** | **Skill** | **Details** |
| **Supervision** | 1 | 1 | Supervisor | Checking the preparation of tools and number of items |
| **Marking** | | 1 | Mason | Site preparation and marking |
| **Handling** | | 9 | Worker | Preparation of tools and various works, deliving equipment |
| | | 0.25 | JCB driver | Moving materials on site |
| **Total** | **1 day = 1 supervisor, 1 mason, 9 workers, 1 JCB driver (2 hours)** | | | |

| EXCAVATION AND LEVELLING THE ROAD | | | | |
|---|---|---|---|---|
| **Task** | **Days** | **Man/day** | **Skill** | **Details** |
| **Supervision** | 2 | 1 | Supervisor | Measuring & checking |
| **Masonry** | | 1 | Mason | Levelling & checking |
| **Digging** | | 9 | Worker | Digging & handling |
| | | 0.25 | JCB driver | Digging road |
| **Total** | **2 days = 1 supervisor, 1 mason, 9 workers, 1 JCB driver (4 hours)** | | | |

| CRUSHING SOIL | | | | |
|---|---|---|---|---|
| **Task** | **Days** | **Man/day** | **Skill** | **Details** |
| **Supervision** | 1 | 1 | Supervisor | Recording data and checking the output of the crusher |
| **Crushing** | | 1 | Machine operator | Operating the crusher |
| | | 7 | Worker | Filling wheelbarrow and filling crusher |
| **Total** | **1 day = 1 supervisor, 1 machine operator, 7 workers** | | | |

| LAYING CURBS | | | | |
|---|---|---|---|---|
| **Task** | **Days** | **Man/day** | **Skill** | **Details** |
| **Supervision** | 2 | 1 | Supervisor | Checking work |
| **Masonry** | | 2 | Mason | Laying the curbs |
| **Handling** | | 4 | Worker | 2 mixing + 2 helpers + 2 Handling |
| **Total** | **2 days = 1 supervisor, 2 masons, 4 workers** | | | |

*Table 8: Workers details per work: Precasting 90 curbs to laying curbs*

| SUB COURSE LAYING AND EMBANKMENT | | | | |
|---|---|---|---|---|
| **Task** | **Days** | **Man/day** | **Skill** | **Details** |
| **Supervision** | 2 | 1 | Supervisor | Checking work |
| **Levelling** | | 2 | Mason | Levelling & checking |
| | | 12 | Worker | Levelling & handling, filling the embankment |
| **Levelling** | 1 | ~0.5 | Bobcat driver | Spreading and levelling gravel on road |
| **Rolling** | 1 | ~0.4 | Roller driver | Compressing gravel of the sub course |
| **Total** | **2 days = 1 supervisor, 2 masons, 12 workers, 1 Bobcat driver (5.5 h.), 1 Roller driver (3 h.)** | | | |

| MIXING POURED EARTH CONCRETE | | | | |
|---|---|---|---|---|
| **Task** | **Days** | **Man/day** | **Skill** | **Details** |
| **Supervision** | 3 | 1 | Supervisor | Measuring, mixing and monitoring |
| **Quality control** | | 2 | Students | Doing the slump test |
| **Measuring** | | 8 | Worker | Measuring & filling mixer: 1 water; 2 binders, 1 chips; 1 red soil; 1 sand & gravel 1/2"; 1 gravel 1.5"; 1 gravel 1" |
| **Mixing** | | 1 | Machine operator | Operating the concrete mixer |
| **Total** | **3 days = 1 supervisor, 8 workers, 1 machine operator, 2 students** | | | |

| CASTING WEARING COURSE | | | | |
|---|---|---|---|---|
| **Task** | **Days** | **Man/day** | **Skill** | **Details** |
| **Supervision** | 3 | 1 | Supervisor | Casting and quality control |
| **Casting** | | 4 | Masons | Casting & levelling (2 levelling, 2 pulling the screed ruler) |
| | | 2 | Machine operator | Operating the vibrators |
| **Handling** | | 6 | Worker | Moving wheelbarrows and 4 to spread PEC |
| **Total** | **3 days = 1 supervisor, 4 masons, 6 workers, 2 machine operators** | | | |

| ROAD SURFACING | | | | |
|---|---|---|---|---|
| **Task** | **Days** | **Man/day** | **Skill** | **Details** |
| **Supervision** | 3 | 1 | Supervisor | Checking work |
| **Handling** | | 3 | Worker | 1 with road scraper, 1 with large broom, 1 pouring water |
| **Total** | **3 days = 1 supervisor, 3 workers** | | | |

| CURING ROAD | | | | |
|---|---|---|---|---|
| **Task** | **Days** | **Man/day** | **Skill** | **Details** |
| **Supervision** | 28 | 1 | Supervisor | Checking work, half an hour per day |
| **Handling** | | 1 | Worker | Curing the road several time per day |
| **Total** | **28 days = 1 supervisor (0.5 h/day), 1 worker** | | | |

*Table 9: Workers details per work: Sub course laying to curing road*

### 4.1.2 Summary of workforce

The units for the following numbers of workers are "man/day".

| WORK | | DAYS | WORKER | MASON | SUPERVISOR | OTHER SKILL |
|---|---|---|---|---|---|---|
| **Precasting curbs** | | 3 | 2 | 1 | 0.25 | - |
| **Site preparation** | | 1 | 9 | 1 | 1 | 0.25 JCB driver |
| **Excavation and levelling the road** | | 2 | 9 | 1 | 1 | 0.25 JCB driver |
| **Crushing soil** | | 1 | 7 | - | 1 | 1 Crusher operator |
| **Laying curbs** | | 2 | 4 | 2 | 1 | - |
| **Sub-Course and embankment** | | 2 | 12 | 2 | 1 | ~0.5 Bobcat driver, ~0.4 Roller driver |
| **Wearing Course** | **Mixing** | 3 | 8 | - | 1 | 1 Mixer operator, 2 Students |
| | **Casting** | | 6 | 4 | 1 | 2 vibrator operator |
| | **Road surfacing** | | 3 | - | | - |
| | **Curing** | 28 | 1 | - | 1 (½ h./day) | - |

*Table 10: Summary of workforce*

## 4.2 SEQUENCES FOR FILLING AND OPERATING THE CONCRETE MIXER

Filling and operating the mixer for poured earth concrete cannot be done with typical procedures for mixing cement concrete. Mixing poured earth concrete must follow a very strict procedure as described hereafter, otherwise the earth will creates a lot of lumps, a thick paste in the mixer, and will not give a homogeneous mix.

Therefore, the sequence of filling the hopper, the drum and operating the mixer were as follows. Mixing a batch of PEC took an average 6-7 minutes including the time of emptying the drum in 2 wheelbarrows.

| Sequence | Volume of materials and containers | Workers |
|---|---|---|
| 1. Pour water in the drum: (~30 s.) | ~56 L. = (2 Buckets 22 L. - 3 L.) + (1 bucket ~15 L.) | 1 worker |
| 2. Load the hopper with: (~1 min. 30 s.) | a) 60 L. Gravel chips = 1 Wheelbarrow 50 L. + 1 bucket 10 L. | 1 worker |
| | b) 38 Kg Cement = 1 bag - 12 Kg which are poured in a box of 42 L. | 1 worker |
| | c) 15 Kg Lime = Box of 42 L. partially filled | 1 worker |
| | d) 75 L. Crushed soil = 1 Wheelbarrow 75 L. | 1 worker |
| | e) 25 L. Sand 4 mm = 1 bucket 15 L. + 1 bucket 10 L. | |
| 3. Lift the hopper to the drum and let it mix for ~1 minute, to get a liquid paste (the time needed to load the larger aggregates in the hopper) | | Mixer operator |
| 4. Load the hopper with: (~1 min.) | a) 50 L. Gravel 1.5" = 1 Wheelbarrow 50 L. | 1 worker |
| | b) 50 L. Gravel 1" (3/4") = 1 Wheelbarrow 50 L. | 1 worker |
| | c) 50 L. Gravel 1/2" = 1 Wheelbarrow 50 L. | 1 worker |
| 5. Lift the hopper to fill the drum and let it mix for ~1 more minute, on the side of the hopper | | Mixer operator |
| 6. Tilt the drum on the other side (opposite the hopper) and keep it as horizontal as possible, without spilling the PEC. Let the drum mix for ~1 more minute | | |
| **Total mixing team = 10 people** = 1 supervisor + 8 workers + 1 concrete mixer operator | | |

*Table 11: Filling sequences of the hopper/mixer and team details*

The mix was often not homogenous for the reason that the drum of the mixer was too small and it was necessary to follow a strict timing and to keep the drum as horizontal as possible, without the mix spilling out. Once the sequence mentioned above was followed, the mix became more homogenous.

## 4.3 SEQUENCE FOR CASTING

Once the poured earth concrete was mixed, the following procedure was followed to cast the wearing course.

1. Unloading the PEC in 2 wheelbarrows and moving them to casting area with 2 workers.
2. Unloading wheelbarrows and spreading them by hand on the same area with 2 workers.
3. Vibrating the PEC with 2 vibrators, immediately after being dumped onto the ground, to reduce the levelling by labour.
4. Two masons and 2 helpers level the PEC with a trowel.
5. Two other masons level the PEC with the steel screed ruler and check that there is no honey comb.
6. Once the PEC has been levelled, 2 masons smoothen the road with an aluminium ruler.

For more details on the casting sequences and the procedure for doing the split joints, see chapter "*7. Photo report with work details*"

The speed of mixing and casting were quite well synchronised and in general masons did not have to wait for a mix. As the mix was not always homogenous, the following procedure was found to be important:

- Drop both wheelbarrows of the same mix on the same area, so that the mix would be homogenised by levelling and vibrating the PEC.
- PEC should be vibrated immediately after being dumped onto the ground, as it reduced the levelling by labour.
- Levelling PEC should be done first with the steel screed ruler to press and level the PEC and then with an aluminium ruler, if necessary to smoothen the PEC to avoid honey comb due to gravel being pulled by the ruler.

## 4.4 SCHEDULE

The road was done in 9 days including the site preparation and cleaning the site:

Site preparation = 1 day
Laying curbs and making the sub course = 4 days
Casting the wearing course = 2.5 days
Cleaning the site, returning tools and materials left over = 1.5 days

From the 5th to 16th March Satprem and Ayyappan were always present on the road and their supervision should be added to these details.

| Dates | Works | Workforce and delivery |
|---|---|---|
| 16-20/02 | - Prefabricating 90 curbs at AVEI | 1 mason, 2 workers |
| 25/02 | - Checking levels with Ayyappan | Ayyappan, Satprem, 1 worker |
| 5/03 | - Delivering tools and site preparation<br>- Marking road levels and levelling the road | 1 supervisor, 1 mason, 6 workers half day at AVEI to load tools, 6 workers on site to unload tools and work, 1 JCB driver<br>Delivery: Equipment, JCB afternoon, CSEB, 3 bags cement, 1 bag lime, 1.5 $m^3$ sand |
| 6/03 | - Road Service delivers soil from Matrimandir: 2 for crushing & 3 for side filling<br>- Delivering curbs on both sides of the road (afternoon)<br>- Laying curbs with 2 masons<br>- Excavation with JCB at both ends of the road<br>- ~3 $m^3$ gravel chips from Visitor's Centre moved on side | 1 Supervisor, 2 masons, 9 workers, 1 JCB driver<br>Delivery: 5 trucks soil, 1 truck gravel chips 1 truck quarry dust, 1 truck gravel ½" 1 truck gravel 1", 1 truck gravel 1.5" 90 curbs + JCB afternoon |
| 7/03 | - Laying curbs and concreting sides of curbs (2 masons)<br>- Laying raw red soil on outer sides of the curbs | 1 Supervisor, 2 masons, 9 workers<br>Delivery: 15 bags cement, 3 bags lime |
| 9/03 | - Unloading cement & lime, concreting sides of curbs<br>- Laying raw red soil on embankment, watering<br>- Delivering on the road 1.5" mixed gravel for sub course<br>- Diego delivers crusher (afternoon) | 1 Supervisor, 2 masons, 12 workers (6 helpers for concreting, 6 for levelling soil, 4 workers for unloading)<br>Delivery: 4 trucks gravel 1.5" mixed, 200 bags cement, 85 bags lime Crusher with belts and other tools |
| 10/03 | - Crushing of soil on site (+) 2 trucks = 22 $m^3$<br>- Levelling gravel of sub course with bobcat and workers<br>- Tamping soil on outer sides of the curbs<br>- Watering again soil on embankment (late afternoon)<br>- Afternoon: Compressing sub course with roller | 1 Bobcat driver,1 Road tamper,1 Roller driver (afternoon),1 Supervisor, 1 mason, 12 workers<br>(7 workers for crushing soil)<br>(5 workers for laying gravel)<br>Delivery: Bobcat, Road tamper, Roller |
| 11-13/03 | - Casting the wearing course (2.5 days)<br>- Returning tools to AVEI | 1 Mixer operator,2 Vibrator operator, 1 Supervisor, 1 Quality Control, 4 masons 8 Workers (Mixing), 6 workers (Casting)<br>Delivery:<br>2 Vibrator from rent, 1 Concrete mixer |
| 14/03 | - Road surfacing and curing<br>- Returning tools to AVEI | 1 Supervisor, 12 workers |
| 14-20/03 | - Curing road (covered with jute cloth) | 1 Worker |
| 16/03 | - Compressing the side road for buses with roller | 6 Workers, 1 Roller driver (morning)<br>Return of Crusher to AVEI |
| 20-22/03 | - Removing jute cloth (20th) from road and going on curing road several times per day (exposed to sun) | 1 Worker |
| 23/03 | - Opening the road | - |
| 23/03 to 10/04 | - Curing road several times per day (exposed to sun) | 1 Worker |

*Table 12: Schedule with work details*

## 4.5 SPILT JOINT

The following plans give the details on how the split joint was created.

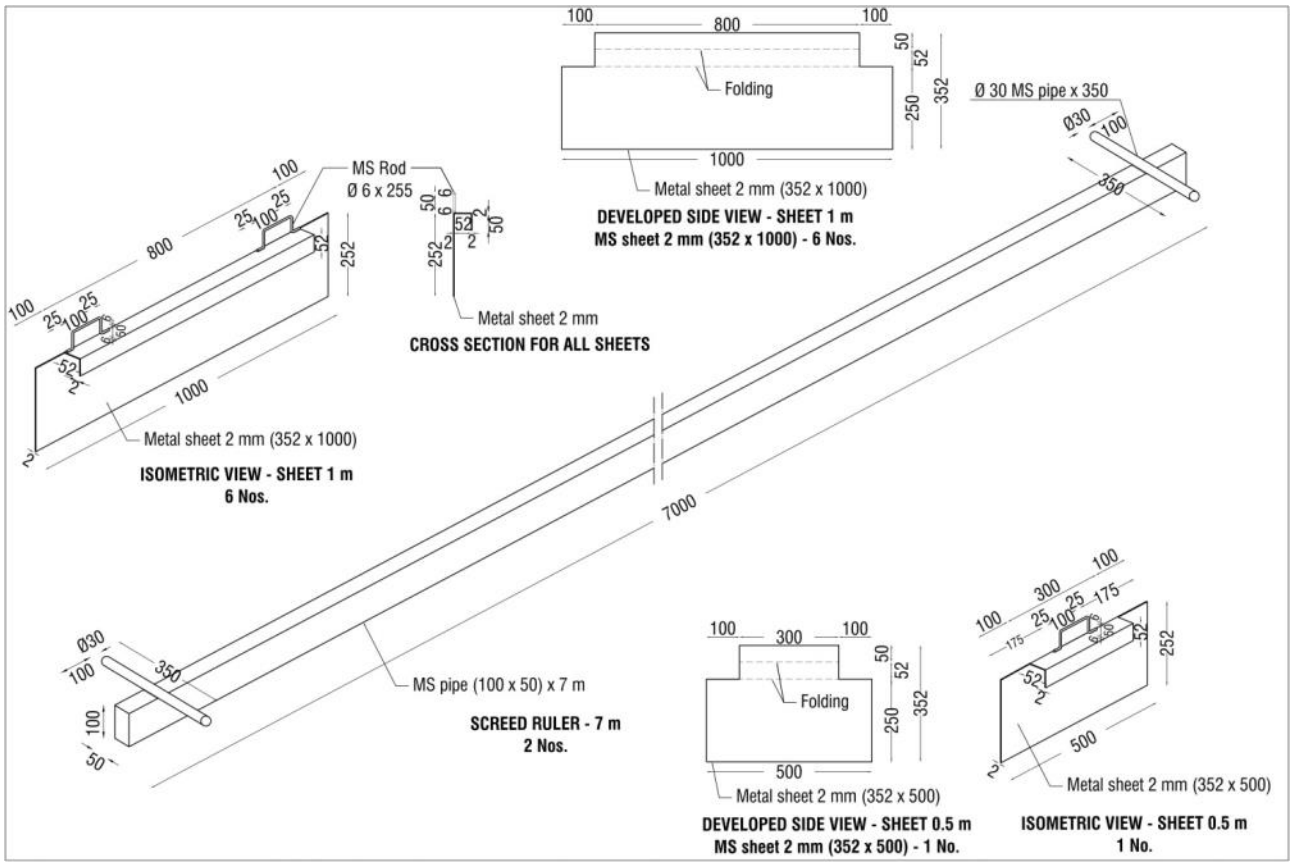



*Fig. 4: Split joint set*

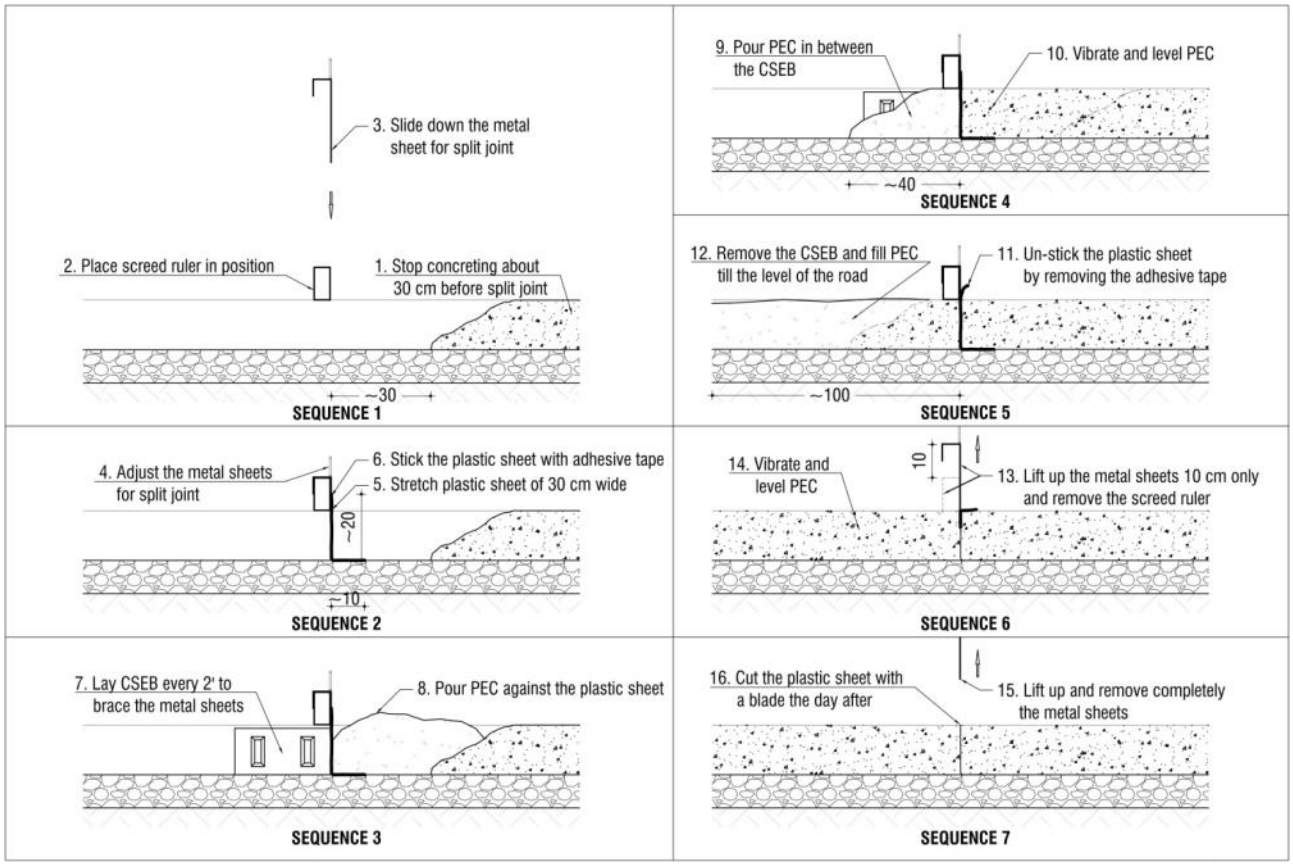



*Fig. 5: Working sequence for the split joint*

# 5. QUANTITIES AND OTHER DATA

## 5.1 FINAL QUANTITIES FOR THE ROAD OF 210 M²

The following table gives details for the road of 210 $m^2$, which was supposed to have a sub course of 10 cm and a wearing course of 15 cm.

In fact, the sub course came to be slightly thicker and the wearing course slightly thinner than expected as the compression ratio due to the roller was less than for the road of December at AVEI. At that time, it was noted that the compression ratio of rolling the sub-course was ~1.25.

Hence, for the road of the Visitor's Centre, the thickness of loose gravel 1.5" mixed was fixed at around 12-13 cm, expecting that it would be compressed up to 10 cm. But the roller compressed it by around only 1-1.5 cm. The reason for this difference was due to the fact that in December, gravel of 1.5"-2" was clean and spread on the road. Later on, the voids between gravel were filled with quarry dust, which was wet afterwards to consolidate it.

The sub course for road of the Visitor's Centre used gravel 1.5" mixed, which had in fact less voids than the clean gravel of December. Thus the compression ratio for rolling the sub course for the road of the Visitor's Centre came to be around 1.1 only. The average thicknesses of the road cast for the Visitor's Centre were as an average as such: 10-11 cm for the sub course and 14 to 15 cm for the wearing course.

| | **Cement** | **Lime** | **Soil** | **Sand 4 mm** | **Gravel Chips** | **Gravel ½"** | **Gravel 1"** | **Gravel 1.5" mixed** | **Gravel 1.5"** | **Water** |
|---|---|---|---|---|---|---|---|---|---|---|
| | (Bag) | (Bag) | ($m^3$) | ($m^3$) | ($m^3$) | ($m^3$) | ($m^3$) | ($m^3$) | ($m^3$) | ($m^3$) |
| **Curbs** | 10 | 2 | 0.6 | 0.6 | 0.6 | 0.6 | - | - | - | 0.5 |
| **Sub-Course & Embankment** | 18 | 4 | 11 Raw | 1 | 1.2 | 1 | 1 | 43 | - | 6 |
| **PEC Road** | 88.5 | 43 | 10.5 Crushed | 3.5 | 7.3 | 5.7 | 5.2 | - | 5.7 | 6.5 Casting 32 Curing |
| **Grand Total** | **106.5** | **47** | **21.5** | **4.5** | **8.5** | **6.7** | **6.2** | **43** | **5.7** | **45** |

*Table 13: Amount of materials used for the road of 210 $m^2$*

The table above shows that a large amount of water was used to cure the road. Obviously the excessive heat of the summer increased the evaporation significantly and obliged is to pour water continuously on the road. For future roads, it would be advisable to build roads in the cooler season and to find way to minimise curing.

## 5.2 QUANTITY REQUIREMENT PER M² OF ROAD

The following table gives the material requirement per square metre of road, as calculated from data collected with the road at the Visitor's centre.

| QUANTITIES OF MATERIALS PER M2 OF ROAD | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ITEM | MIX RATIO FOR WEARING COURSE | | SUB-COURSE | | WEARING COURSE | | TOTAL ROAD (DELIVERY) | |
| | | | Thickness (cm) | 10 | Thickness (cm) | 15 | Area ($m^2$) | 1 |
| | | | | | | | Length (m) | 1 |
| | Unit | Unit | Qty/road | Unit | Qty/road | Unit | Qty/road | Unit |
| Cement **(~8 % = 38 Kg/mix)** | **38** | Kg/mix | 0.41 | Bag | 0.43 | Bag | **0.83** | **Bag** |
| Lime **(~3 % = 15 Kg/mix)** | **15** | Kg/mix | 0.08 | Bag | 0.21 | Bag | **0.29** | **Bag** |
| Red soil raw laying curbs, Embankment | - | - | 0.279 | $m^3$ | - | - | **0.28** | **$m^3$** |
| Red Soil crushed | **75** | L/mix | 0 | $m^3$ | 0.042 | $m^3$ | **0.04** | **$m^3$** |
| Sieved sand 4mm or quarry dust 2mm | **25** | L/mix | 0 | $m^3$ | 0.014 | $m^3$ | **0.01** | **$m^3$** |
| Sieved sand 4mm or quarry dust 2mm | **-** | - | 0.024 | $m^3$ | - | - | **0.02** | **$m^3$** |
| Gravel Chips | **60** | L/mix | 0 | $m^3$ | 0.034 | $m^3$ | **0.03** | **$m^3$** |
| Gravel 1/2" | **50** | L/mix | 0.024 | $m^3$ | 0.028 | $m^3$ | **0.05** | **$m^3$** |
| Gravel 1" | **50** | L/mix | 0.024 | $m^3$ | 0.028 | $m^3$ | **0.05** | **$m^3$** |
| 1.5" aggregates | **50** | L/mix | 0 | $m^3$ | 0.028 | $m^3$ | **0.03** | **$m^3$** |
| 1.5" aggregates mixed | **-** | - | 0.165 | $m^3$ | - | - | **0.17** | **$m^3$** |
| Curbs 1m (PEC 1: 0.5: 2: 2: 2: 2) | - | - | 2 | Nos. | - | - | **2.00** | **Nos.** |
| Water for soaking sub course+casting | **56** | L/mix | 0.031 | $m^3$ | 0.031 | $m^3$ | **0.06** | **$m^3$** |
| Water curing | **150** | $L/m^2$ | 0 | $m^3$ | 0.150 | $m^3$ | **0.15** | **$m^3$** |

*Table 14: Material requirement per $m^2$ of road*

## 5.3 CRUSHING STRENGTH OF ROAD SAMPLES

Six cylindrical samples, of 1' diameter and 1' height, were made while casting the road on the 12th March 2015. They have been cured for 4 weeks and then left to dry for 12 weeks. The samples have been tested on the 13th July 2015 for the dry strength and the 14th July 2015 for the wet strength, after 48 hours immersion.

| Sample Ref. | Air dry weight (Kg) | Volumic Mass ($Kg/m^3$) | Wet weight (69 h) (Kg) | Water absorption (%) | Crushing strength (MPa) |
|---|---|---|---|---|---|
| **1 dry** | 49.81 | 2,250 | - | - | 11.79 |
| **2 dry** | 49.79 | 2,249 | - | - | 13.29 |
| **3 dry** | 49.47 | 2,235 | - | - | 13.10 |
| **4 wet** | 48.98 | 2,285 | 50.59 | 3.3 | 11.18 |
| **5 wet** | 49.12 | 2,292 | 50.73 | 3.2 | 11.28 |
| **6 wet** | 49.35 | 2,305 | 51.02 | 3.3 | 10.74 |

*Table 15: Strength of samples*

## 5.4 TOOL REQUIREMENT

| MACHINERY | |
|---|---|
| **Item** | **Nos.** |
| Concrete mixer 10/7 CFT | 1 |
| Vibrator | 3 |
| Bobcat | 1 |
| Crusher set with canvas cover | 1 |
| Fuel for machines | 3 |
| 2 KVA generator | 1 |
| Extension cable 50 m | 1 |
| Heavy duty grinding machine + 2 stone disk | 1 |
| Extension cable for crusher, 40 m (3 phase) | 1 |
| | |
| | |
| | |
| | |
| | |
| | |
| **HANDLING & CONTAINERS** | |
| **Item** | **Nos.** |
| Wheelbarrow flat | 2 |
| Wheelbarrow 50 L. | 5 |
| Wheelbarrow 75 L. | 2 |
| Wheelbarrow 100 L. | 2 |
| Wheelbarrow 200 L. | 2 |
| Plastic barrel 200 L.<br>(3 mixing concrete + 1 engine mixer) | 4 |
| Plastic barrel 100 L.<br>(1 Engine mixer + 1 road casting) | 2 |
| Pan | 10 |
| Mortar mixing pan (116 x 116) | 1 |
| Aluminium bucket 11L. | 6 |
| Aluminium bucket 15 L. | 6 |
| Plastic bucket 22 L. | 4 |
| Steel box 42 L. | 2 |
| Measuring cylinder 2 L. | 1 |
| Measuring cylinder 1 L. | 1 |
| Measuring cylinder 0.5 L. | 1 |
| Plastic can 35 l. with diesel | 1 |
| Drinking water can 25 L with tap | 2 |
| Stainless steel glass | 2 |
| Steel box 82 x 42 x 30 cm for small tools | 1 |
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| HAND TOOLS | |
|---|---|
| **Item** | **Nos.** |
| Crow bar | 3 |
| Hoe | 10 |
| Shovel | 10 |
| Mason tool sets | 3 |
| Hard broom for floor | 4 |
| Large broom | 3 |
| Steel rake | 3 |
| Scraper (for SREF) | 2 |
| Roll of string line | 1 |
| ∅ 12 mm rod ~ 1 m | 12 |
| Sledge hammer | 1 |
| Tube level 30 m | 1 |
| Rammer 200 | 4 |
| Rammer 100 | 4 |
| Tools set (various spanners, screw driver, etc.) | 1 |
| **SPECIAL TOOLS** | |
| **Item** | **Nos.** |
| Screed ruler with handles 10 x 5 cm x 7 m | 1 |
| Screed ruler with handles 10 x 5 cm x 5 m | 2 |
| Aluminium rule 4" x 2" x 12' | 2 |
| Aluminium rule 2" x 1" x 6' | 2 |
| Slump test set (cone, rod, scale, plywood) | 1 |
| Hose pipe | 80 m |
| Hose pipe carrier | 1 |
| Scale (300 Kg) | 1 |
| Wooden ramp (mixer & crusher) | 2 |
| Extra wooden ramp | 1 |
| Boots & goggle & dust mask | 8 |
| Rubber gloves | 12 |
| Leather gloves | 8 |
| Dust mask | 50 |
| Road scraper with wire brushes | 2 |
| Split joint separator set (7 m rule, 6.5 m sheets) | 1 |
| Tarpaulin 15 x 15 m | 1 |
| Tarpaulin 18 x 14 m | 1 |
| Tarpaulin 12 x 8.5 m | 2 |
| Tarpaulin 9 x 9 m | 1 |
| 10 m chain with lock | 1 |
| 50 m tape (Plastic tape) | 1 |
| 50 m tape (steel tape) | 1 |
| 7.5 m tape | 2 |
| Thick rope (~1 cm ∅) | 50 m |
| Chalk line | 2 |
| First aid kit | 1 |
| Paper cutter with spare blades | 1 |
| Cylinders for casting samples (∅30.5 x 30 cm) | 6 |
| Marine plywood (casting samples) 1.2 x 1.2 m | 1 |

*Table 16: Tool requirement*

# 6. ROAD COST

## 6.1 COST ANALYSIS OF THE ROAD

The road with the section and profile as described earlier, with 10-11 cm thick sub-course and 14-15 cm thick wearing course came to 1,593.4 Rs./$m^2$. The cost breakdown below shows the following:

- Cost of sub-course with curbs and embankment= 714.7 Rs./$m^2$ with a labour cost of 46.04%.
  This percentage is half the cost as in Dec. 2014 (80.46%) for the reason that a JCB was used to dig the road and a bobcat was used to level the gravel of the sub course.
- Cost of wearing course = 878.7 Rs./$m^2$ with a labour cost of 45.20%
  This percentage is more than in Dec. 2014 (25.04%), probably for the reason that split joints were added and more labour was used in March 2015.
- The total labour cost represents 45.58% and material cost 54.42%.

**POURED EARTH CONCRETE ROAD AT VISITORS' CENTRE - COST ANALYSIS**

**Road Area (m2) = 210** **Road length (m) = 44**

**LAYING CURBS AND SUB COURSE 10 cm Thick**

| Materials & equipment for Sub Course | | | | | Labour for Sub Course | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Item | Unit | Qty | Rate | Amount | Item | Days | Nos. & Skill | Rate | Qty | Amount |
| Cement | Bag | 18.00 | 385 | 6,930 | Tools & Site preparation | 1 | 9 Workers | 455 | 9 | 4,095 |
| Lime | Bag | 4.00 | 430 | 1,720 | | | 1 Mason | 835 | 1 | 835 |
| Red Soil raw | $m^3$ | 11.00 | 200 | 2,200 | | | 1 Supervisor | 2,215 | 1 | 2,215 |
| Quarry dust (not used) | Truck | 1.00 | 4,500 | 4,500 | | | 1 JCB driver | 1,000 | 1 | 1,000 |
| Gravel Chips | $m^3$ | 1.23 | 420 | 517 | Excavation | 2 | 9 Workers | 455 | 18 | 8,190 |
| 1/2" aggregates | $m^3$ | 1.00 | 450 | 450 | | | 1 Mason | 835 | 2 | 1,670 |
| 1" aggregates | $m^3$ | 1.00 | 685 | 685 | | | 1 Supervisor | 2,215 | 2 | 4,430 |
| 1.5" aggregates mixed | $m^3$ | 43.00 | 500 | 21,500 | | | 1 JCB driver | 1,000 | 2 | 2,000 |
| Curbs | Nos. | 90 | 250 | 22,500 | Curb laying | 2 | 9 Workers | 455 | 18 | 8,190 |
| Water (tap) | $m^3$ | 6.00 | 0 | 0 | | | 2 Masons | 835 | 4 | 3,340 |
| Roller | Hour | 3 | 500 | 1,500 | | | 1 Supervisor | 2,215 | 2 | 4,430 |
| JCB site preparation | Hour | 2 | 625 | 1,250 | Gravel laying & side curb filling | 2 | 12 Workers | 455 | 24 | 10,920 |
| JCB Excavation | Hour | 2 | 625 | 1,250 | | | 2 Mason | 835 | 4 | 3,340 |
| Bobcat gravel laying | Hour | 5.5 | 550 | 3,025 | | | 1 Supervisor | 2,215 | 2 | 4,430 |
| Red soil for sides curbs | $m^3$ | 12.00 | 200 | 2,400 | | | 1 Bobcat driver | 1,000 | 1 | 1,000 |
| Subtotal Cost Mat. & Equipt. Sub Course | | | | 80,991 | Subtotal Labour Cost Sub Course | | | | | 69,098 |
| Percentage Cost Mat. & Equipt. Sub Course | | | | 53.96% | Percentage Labour Cost Sub Course | | | | | 46.04% |
| SUBTOTAL COST OF SUB COURSE (Rs.) | | | | 150,088 | SUBTOTAL COST OF SUB COURSE (Rs./m2) | | | | | 714.7 |

**Note for bobcat:** Quantities are for (1/2 site preparation) + (1/2 excavation) + (gravel laying) + (casting for material supply)

**WEARING COURSE 15 cm Thick**

| Materials & equipment for Wearing Course | | | | | Labour for Wearing Course | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Item | Unit | Qty | Rate | Amount | Item | Days | Nos. & Skill | Rate | Qty | Amount |
| Cement | Bag | 88.50 | 385 | 34,073 | Casting | 3 | 14 Worker | 455 | 42 | 19,110 |
| Lime | Bag | 43.00 | 430 | 18,490 | | | 4 Mason | 835 | 12 | 10,020 |
| Red Soil crushed | $m^3$ | 10.50 | 250 | 2,625 | | | 1 Supervisor | 2,215 | 3 | 6,645 |
| Quarry dust 2 mm* | $m^3$ | 3.50 | 1,650 | 5,775 | | | 1 Quality cont. | 1,280 | 3 | 3,840 |
| Gravel Chips | $m^3$ | 7.30 | 420 | 3,066 | | | 2 Vibrator oper | 835 | 6 | 5,010 |
| 1/2" aggregates | $m^3$ | 5.70 | 450 | 2,565 | | | | | | |
| 1" aggregates | $m^3$ | 5.20 | 685 | 3,562 | Road surfacing | 3 | 3 Worker | 455 | 9 | 4,095 |
| 1.5" aggregates clean | $m^3$ | 5.70 | 565 | 3,221 | | | 1 Supervisor | 2,215 | 3 | 6,645 |
| Water casting (tap) | $m^3$ | 12.00 | 0 | 0 | Curing | 28 | 1 Worker | 455 | 28 | 12,740 |
| Water curing (tap) | $m^3$ | 18.00 | 0 | 0 | | | 1 Supervisor | 2,215 | 2 | 4,430 |
| Vibrator machine | Day | 3.00 | 1,100 | 3,300 | | | | | | |
| Concrete mixer | Day | 3.00 | 2,350 | 7,050 | | | | | | |
| Transport (Ace) | Unit | 12.00 | 350 | 4,200 | | | | | | |
| Transport Road Service | Unit | 7.00 | 350 | 2,450 | Miscellaneous % added for every subtotal | | | | 15 | |
| Subtotal Cost Mat. & Equipt. Wearing Course | | | | 101,115 | Subtotal Cost Labour Wearing Course | | | | | 83,415 |
| % Cost Mat. & Equipt. Wearing Course | | | | 54.80% | Percentage Cost Labour Wearing Course | | | | | 45.20% |
| SUBTOTAL COST OF WEARING COURSE (Rs.) | | | | 184,530 | SUBTOTAL COST OF WEARING COURSE (Rs./m2) | | | | | 878.7 |
| % Cost Material & Equipment for Entire Road | | | | 54.42% | Percentage Cost Labour for Entire Road | | | | | 45.58% |
| Percentage Cost of Sub Course (10 cm thick) | | | | 44.85% | Percentage Cost of Wearing Course (15 cm thick) | | | | | 55.15% |
| GRAND TOTAL COST OF ROAD (Rs.) | | | | 334,618 | GRAND TOTAL COST OF ROAD (Rs./m2) | | | | | 1,593.4 |

*Table 17: Cost analysis*

## 6.2 COST COMPARISON BETWEEN PEC ROAD AND OTHER ROADS BY ROAD SERVICE

This section attempts to compare the cost between this PEC road and two types of roads done by the Auroville Road Service:

- Stabilised with gravel and silt (Only 15 cm thick gravel and silt on top: No cement stabilisation)
- Concrete paver block (8 cm thick) laid on a sub course (22 cm thick) made of 3 layers of various aggregates.

Two cost estimates done in 2014 ("*Sincerity Gate Road 38m*" and "*Mangalam stabilised road 240m*") by the Road Service were communicated to us. In order to compare the same kinds of works which were done with the PEC road, some amounts estimated by the Road Service were not accounted for in the costs mentioned below (Clearing the land, fencing, HDPE pipes, lorry apron, shaping channel, inner shoulder, signage, street light, speed bumps)

These calculations show that:

- PEC road is ~59.5% cheaper than the concrete paver block road.
- PEC road is ~229.5% costlier than the stabilised road with gravel & silt. However this type of road is not permanent and much weaker than PEC road or concrete paver block road. Stabilised road with gravel & silt will need maintenance that the PEC will not need. Further stabilised road with gravel & silt produce much more dust from traffic.

| TYPE OF ROAD | SUB COURSE COST | WEARING COURSE COST | TOTAL COST |
|---|---|---|---|
| **PEC road** | **714.7 Rs./m²**<br>**= 44.7% cheaper than pavers** | **878.7 Rs./m²**<br>**= 81.4% cheaper than pavers** | **1,593.4 Rs./m²**<br>**= 59.5% cheaper than pavers** |
| **Concrete paver blocks** | 1,597.7 Rs./m²<br>**= 223.5% costlier than PEC** | 1,080.1 Rs./m²<br>**= 122.9% costlier than PEC** | 2,677.7 Rs./m²<br>**= 168% costlier than PEC** |
| **Stabilised with gravel & silt** | - | - | 532 Rs./m²<br>**= 299.5% cheaper than PEC** |

*Table 18: Cost comparison between PEC road and two roads of the Road Services*

**Note:** The sub course of the concrete paver block road is so expensive because it is composed of 3 layers of various aggregates (∅ 40mm, 10 cm thick – ∅ 20mm, 8 cm thick – ∅ 8mm, 4 cm thick) and the spreading of the gravel is done by hand by the workers of the road service.

# 7. PHOTO REPORT WITH WORK DETAILS

*Fig. 6: Delivery of materials*
Delivery of gravel of various sizes along the road

*Fig. 7: Delivery of materials*
Delivery of materials along the road: Soil and curbs

Fig. 8: Levelling base for curbs
Filling rubble in depressions to get the level for the curbs

Fig. 9: Levelling base for curbs
Laying mortar CSM 1: 3 to get the level for the curbs

Fig. 10: Levelling base for curbs
Checking the level of the mortar CSM 1: 5 before laying the curbs

Fig. 11: Levelling base for curbs
Laying mortar CSM 1: 5, between two ruler guides, for levels of curbs

*Fig. 12: Excavation at the end of the road*
Excavation with the JCB at both ends of the road only: The road was relatively levelled in the central portion.

*Fig. 13: Excavation at the end of the road*
Excavation with the JCB: loading the materials by hand in the JCB's bucket

*Fig. 14: Laying curbs*
Laying the curbs on mortar CSM 1: 3

*Fig. 15: Adjusting the curbs*
Adjusting the curb to be aligned with the string line

*Fig. 16: Marking the levels*
Marking levels for concreting the curbs: 15 cm inside and 12.5 cm outside of the curbs

*Fig. 17: Marking the levels*
Marking the concreting level with a chalk line: 15 cm inside and 12.5 cm outside of the curbs

*Fig. 18: Concreting the curbs*
Concreting the curbs outside with PEC 1: 0.25: 2: 2: 2: 2
12.5 cm below the top level of curbs

*Fig. 19: Concreting the curbs*
Concreting the curbs inside with PEC, 15 cm below the top level of curbs, which is the thickness of the wearing course.

*Fig. 20: Filling the embankment*
Filling the embankment with red soil and/or rubble and levelling

*Fig. 21: Filling the embankment*
Filling the embankment with red soil and/or rubble and watering

*Fig. 22: Ramming the embankment*
Ramming the embankment with a road tamper from the road service

*Fig. 23: Ramming the embankment*
Ramming the embankment with a hand rammer near the curbs, not to damage them

*Fig. 24: Delivery of gravel 1.5" mixed*
Delivery of gravel 1.5" mixed in the middle of the road

*Fig. 25: Delivery of gravel 1.5" mixed*
Delivery of gravel 1.5" mixed in the middle of the road, by spreading the piles

*Fig. 26: Levels for the sub course*
Making levels with blocks for the top level of the sub course: 15 cm below the top of the curb

*Fig. 27 Levels for the sub course*
Fixing a blocks for the top level of the sub course

*Fig. 28: Levelling the sub course with a bobcat*
Levelling the sub course with the bobcat of Matrimandir

*Fig. 29: Levelling the sub course with a bobcat*
Levelling the sub course with the bobcat of Matrimandir

*Fig. 30: Checking levels of sub course*
Mason checking the level of the sub course from the screed ruler

*Fig. 31: Levelling the sub course*
Levelling the sub course with a rake to get the proper level

*Fig. 32: Levelling the sub course*
Levelling gravel of the sub course by hand and with the bobcat

*Fig. 33: Checking levels of sub course*
Mason checking the final level of the sub course after levelling

*Fig. 34: Watering the sub course*
Watering the sub course with a hose pipe, before rolling

*Fig. 35: Watering the sub course*
Watering the sub course with the tanker from the Road Service

*Fig. 36: Compressing the sub course*
Compressing the sub course with the roller from the Road Service

*Fig. 37: Compressing the sub course*
Compressing the sub course with the roller and by hand rammer on the sides, not to damage the curbs

*Fig. 38: Brushing the sub course*
Brushing the sub course with large brooms, to remove the fine dust for a better grip between sub course and PEC

*Fig. 39: Texture of the sub course before concreting*
Texture of the sub course before concreting: Indispensable to be rough to give grip for the PEC

*Fig.40Tractor of Diego in the ditch*
Tractor of Diego was pushed into the ditch by a careless truck driver. Luckily Diego was not injured and the crusher was only a little damaged.

*Fig. 41: Crusher arriving to the site*
Diego arriving safely to the site with the crusher, after being put back on the road

*Fig. 42: Crusher in operation*
Soil crusher designed by AVEI in operation

*Fig. 43: Crusher in operation*
Loading 50 L. wheelbarrows of soil in the hopper of the crusher

*Fig. 44: Bobcat moving crushed soil*
Bobcat moving crushed soil away from the crusher

*Fig. 45: Bobcat moving crushed soil*
Bobcat delivering crushed soil on the side of the road

*Fig. 46: Mixer in operation*
Filling water to cool down the engine

*Fig. 47: Mixer in operation*
Lifting the first batch of aggregates into the drum

*Fig. 48: Measuring lime (15 Kg)*
Weighing 15 Kg of lime on the scale

*Fig. 49: Measuring cement (38 Kg)*
Weighing 38 Kg of cement on the scale

*Fig. 50 Measuring water (56 L.)*
Measuring 56 Litres of water in buckets of 22 and 15 litres

*Fig. 51: Filling water in the drum*
Filling water in the drum, while workers are filling the hopper with materials

*Fig. 52: Filling the hopper - 1st gravel chips*
Filling hopper with 60 litres gravel chips (50 L. wheelbarrow & 10 L. bucket)

*Fig. 53: Filling the hopper - 2nd cement*
Filling hopper with 38 Kg cement

*Fig. 54: Filling the hopper - 3rd lime*
Filling hopper with 15 Kg lime

*Fig. 55: Filling the hopper - 4th soil*
Filling hopper with 75 litres soil
(75 L. wheelbarrow)

*Fig. 56: Filling the hopper - 5th sand*
Filling hopper with 25 litres sand
(1 bucket 15 L. + 1 bucket 10 L.)

*Fig. 57: Lifting the hopper to the drum*
Lifting the hopper while workers are measuring the next batch

*Fig. 58: Filling the hopper - 6th Gravel 1.5"*
Filling hopper with 50 litres gravel 1.5"
(50 L. wheelbarrow)

*Fig. 59: Filling the hopper - 7th gravel 1"*
Filling hopper with 50 litres gravel 1"
(50 L. wheelbarrow)

*Fig. 60: Filling the hopper - 8th gravel 1/2"*
Filling hopper with 50 litres gravel *1/2"*
(50 L. wheelbarrow)

*Fig. 61: Lifting the hopper to the drum*
Lifting the hopper while workers are measuring the next batch with soil

*Fig. 62: Emptying the drum*
Consistency of the PEC while emptying

*Fig. 63: Filling the wheelbarrow*
Emptying the drum while workers are measuring the next batch with soil

*Fig. 64: Slump test*
Doing a slump test to check the fluidity

*Fig. 65: Slump test*
Settlement of sample ~33 mm for a proper consistency

*Fig. 66: Emptying the wheelbarrow*
Emptying the wheelbarrow on site

*Fig. 67: Levelling PEC*
Levelling the PEC with a rake

*Fig. 68: Emptying the wheelbarrow*
Emptying the wheelbarrow on site and vibrating the PEC

*Fig. 69: Vibrating the PEC*
Spreading the PEC and vibrating it

*Fig. 70: Vibrating the PEC*
Spreading the PEC and vibrating it

*Fig. 71: Levelling PEC*
Spreading and levelling the PEC with a trowel

*Fig. 72: Levelling PEC with screed ruler*
Levelling PEC with screed ruler, pulled by two masons

*Fig. 73: Levelling PEC with screed ruler*
Levelling PEC with screed ruler, by pulling it back and forth

*Fig. 74: Touch up*
Touch up with a trowel to smoothen the PEC

*Fig. 75: Touch up*
Touch up with a trowel to smoothen the PEC

*Fig. 76: Shrinkage crack*
Shrinkage crack developed due to excessive surface temperature and evaporation (35 °C air temperature under shade but 50 °C for the surface temperature of the ground)

*Fig. 77: Repairing shrinkage cracks*
Repairing shrinkage cracks by pouring a little water into the cracks and pressing with the trowel

*Fig. 78: Covering with jute cloth*
Protecting the road after ~2 hour with the wet jute cloth

*Fig. 79: Covering with jute cloth*
Spreading the wet jute cloth to protect the road

*Fig. 80: Inserting metal sheet for split joint*
Inserting 1 m long metal sheets for split joint, fixed on the screed ruler

*Fig. 81: Pulling the plastic sheet for split joint*
Stretching the plastic sheet to avoid PEC to stick on the metal sheets

*Fig. 82: Taping the plastic sheet*
Taping the plastic sheet on the metal sheets with an adhesive tape to hold it in place

*Fig. 83: Spreading the PEC against the plastic sheet*
Once the plastic sheet is set, the PEC is poured against it.

*Fig. 84: Block to hold the metal sheets*
Blocks holding the metal sheets in place, while PEC is levelled in front of the split joint.

*Fig. 85: Pulling the screed ruler*
Screed ruler is pulled back and forth in front of the split joint.

*Fig. 86: Casting PEC in front of split joint*
PEC is levelled and vibrated in front of the split joint.

*Fig. 87: Levelling PEC in front of split joint*
The screed ruler is pulled back and forth to level the PEC.

*Fig. 88: Smoothening the PEC*
Smoothening the PEC in front of the split joint

*Fig. 89: Dropping PEC against split joint*
PEC is poured against the back of the metal sheets of the split joint, while masons finish to level PEC in front

*Fig. 90: Pushing PEC against metal sheets*
PEC is pushed against the back of the metal sheets of the split joint

*Fig. 91: Unloading wheelbarrows of PEC*
PEC is unloaded at the back of the metal sheets of the split joint.

*Fig. 92: Levelling PEC*
Levelling PEC with a rake and vibrating it

*Fig. 93: Vibrating PEC*
Vibrating PEC and levelling it with the screed ruler

*Fig. 94: Metal sheet pulled out*
Metal sheets are pulled out by ~10 cm, after removing the adhesive tape and once PEC is levelled on either side of them

*Fig. 95: Levelling PEC*
Levelling PEC with the screed ruler

*Fig. 96: Pulling out metal sheets*
Metal sheets of split joint are totally pulled out once the PEC is totally levelled.

*Fig. 97: Plastic sheet folded on PEC*
Plastic sheet of split joint lean on the finished PEC

*Fig. 98: Cutting plastic sheet*
Plastic sheet of split joint is cut with a cutter one day after casting

*Fig. 99: Surfacing the road*
Road is scratch with the special road scratcher, one day after casting

*Fig. 100: 50 Kg to load road scratcher*
50 Kg are need to load the road scratcher

*Fig. 101: Detail of road scratcher*
Top view of road scratcher

*Fig. 102: Detail of road scratcher*
Bottom view of road scratcher with wire brushes

*Fig. 103: PEC road finish after smoothening*
Very smooth finish of PEC just after smoothening with the screed ruler

*Fig. 104: Scratched surface of PEC*
Finish of PEC after scratching, with grains of gravel chips for better grip of tyres

*Fig. 105: Scratched surface of PEC*
Finish of PEC after scratching, with marks of wire brushes for better grip of tyres

*Fig. 106: Auroville Earth Institute team*

# 8. RECOMMENDATIONS FOR FUTURE ROADS

## 8.1 MIX RATIO

The third and last mix ratio used for the road of the Visitor's centre gave good results for the workability of the mix. However, the clayey silt soil from Matrimandir showed initial shrinkage cracks due to the surface temperature and because of the increase of clay and silt in the soil. The road cast in Dec. 2014 at AVEI premises showed also 2 major shrinkage cracks and many minor hair cracks which developed in March 2015, at the time of casting the Visitor's Centre road, on account of the summer heat. Therefore it appears that the PEC road exposed to direct sun is more sensitive to heat than PEC cast in walls. Thus, it seems that the PEC is not ductile enough to accommodate contraction and dilatation due to heat variation.

These remarks lead us to propose a different mix ratio for the future road, in order to increase the ductility of the PEC while still keeping sufficient strength and abrasion resistance. Hence the following mix is proposed for the future road. Cement has been reduced, as it gives less elastic materials and lime has been increased, as it could give a mix more ductility and add strength in the long run.

| Item | Measurement | % by weight | Container details |
|---|---|---|---|
| Cement | 25 Kg | 5.430 | 1/2 bag (poured in a box of 42 L.) |
| Lime | 25 Kg | 5.430 | Box of 42 L. (partially filled) |
| Red soil | 75 L. | 24.106 | 1 Wheelbarrow 75 L. |
| Coarse sand or quarry dust 2mm | 25 L. | 8.760 | 1 bucket 15 L. + 1 bucket 10 L. |
| Gravel chips | 60 L. | 18.456 | 1 Wheelbarrow 50 L. + 1 bucket 10 L. |
| Gravel ½" | 50 L. | 15.945 | 1 Wheelbarrow 50 L. |
| Gravel 1" | 50 L. | 16.683 | 1 Wheelbarrow 50 L. |
| Gravel 1.5" | 50 L. | 16.050 | 1 Wheelbarrow 50 L. |
| Water (main casting) | 56 L. | 11.537 | (2 Buckets 22 L. - 3 L.) + (1 bucket ~15 L.) |

*Table 19: Proposed mix ratio for future road*

Six cylinders have been cast on the 20th March 2015, to test the crushing strength after 4 months and decide if this mix will be strong enough for future roads. These samples will be tested on 20th July 2015.

Note that the mix ratio mentioned above may be adapted according to the soil quality and the result of the shrinkage test, which are being conducted presently at AVEI. This shrinkage tests aims to elaborate a protocol which would allow the determination of an appropriate mix ratio for PEC roads. Some samples are presently being tested and results will be obtained in May.

Adding fibres (i.e. Recon 3 S) might be envisaged to reduce shrinkage and increase ductility and tensile resistance of the PEC road. The shrinkage test being presently conducted at AVEI, included some samples done with these Recon 3 S fibres.

**Note for water proportions and slump test**

- Water quantity will be finalised in situ according to the moisture content of materials and the mix workability. Slump test should be kept around 30 mm.
- More attention should be paid to have a more homogeneous mix in the drum:
- Timings should be kept as mentioned in the nest paragraph and the drum should be kept as horizontal as possible in the last phase of wet mixing.
- More attention should be paid to take representative samples for the slump test: Samples for slump tests should be taken once the mix is on the ground, and taken from a homogeneous part.
- Water content may change during the course of a very hot day, as materials may absorb more water as they dry.

## 8.2 SEQUENCES FOR FILLING AND OPERATING THE CONCRETE MIXER

Sequence of filling the hopper and the drum of the mixer would follow the same sequence as last time, with only a slight difference for quantities of cement and lime. Remember that the following mix ratio may have to be adapted according to the soil quality and the result of the shrinkage test.

| Sequence | Volume of materials and containers | Workers |
|---|---|---|
| 1. Pour water in the drum: (~30 s.) | ~56 L. = (2 Buckets 22 L. - 3 L.) + (1 bucket ~15 L.)<br>This quantity must be experimented first to get ~33 mm slump test. | 1 worker |
| 2. Load the hopper with: (~1 min. 30 s.) | a) 60 L. Gravel chips = 1 Wheelbarrow 50 L. + 1 bucket 10 L. | 1 worker |
| | b) 25 Kg Cement = 1/2 bag which is poured in a box of 42 L. | 1 worker |
| | c) 25 Kg Lime = Box of 42 L. partially filled | 1 worker |
| | d) 75 L. Crushed soil = 1 Wheelbarrow 75 L. | 1 worker |
| | e) 25 L. Sand 4 mm = 1 bucket 15 L. + 1 bucket 10 L. | |
| 3. Lift the hopper to the drum and let it mix for ~1 minute, to get a liquid paste (the time needed to load the larger aggregates in the hopper) | | Mixer operator |
| 4. Load the hopper with: (~1 min.) | a) 50 L. Gravel 1.5" = 1 Wheelbarrow 50 L. | 1 worker |
| | b) 50 L. Gravel 1" (3/4") = 1 Wheelbarrow 50 L. | 1 worker |
| | c) 50 L. Gravel 1/2" = 1 Wheelbarrow 50 L. | 1 worker |
| 5. Lift the hopper to fill the drum and let it mix for ~1 more minute, on the side of the hopper | | Mixer operator |
| 6. Tilt the drum on the other side (opposite the hopper) and keep it as horizontal as possible, without spilling the PEC. Let the drum mix for ~1 more minute | | |
| **Total mixing team = 10 people** = 1 supervisor + 8 workers + 1 concrete mixer operator | | |

*Table 20: Filling sequences of the hopper/mixer (Future road)*

## 8.3 VARIOUS RECOMMENDATIONS

- A PEC road should not be done in the hot season to limit shrinkage, to maintain even workability and to reduce excessive labour during hot weather. It is preferable to do it in the coolest time of the year.
- Check the soil quality before doing the road and conduct some shrinkage tests (See new AVEI protocol).
- Check again the bulk densities of all materials, so as to accurately calculate the new percentages. This would give the actual bulk density of materials filled in the mixer. This protocol should be followed:
  1. Check the exact volume of all containers used on site for measuring materials (Wheelbarrows, buckets, boxes).
  2. Measure the weight of these empty containers used for measuring materials.
  3. Fill containers according to requirements.
  4. Weight the containers with the material inside and calculate the actual bulk densities
- The soil should be crushed elsewhere and transported to the site. It should be covered very well with a tarpaulin.
- All materials should be piled up near the stretch of road to be cast, close to the mixer machine.
- All piles of aggregates should be covered with tarpaulins as they should be preferably dry.
- The distance between split joints may be reduced. There could be a split joint every 6 m.
  This could be decided according to the behaviour of the Visitor's Centre road and the shrinkage test results.
- Wheelbarrows of the same mix should be emptied on the same area, so that the mix would be homogenised by levelling and vibrating the PEC.
- The PEC should be vibrated immediately after being dumped onto the ground, as it reduces the levelling by labour.
- Level first the PEC with the steel screed ruler so as to press it and level it.
- Fill any hole created by gravel which may be pulled out by the steel screed ruler.
- Level again the PEC with an aluminium ruler so as to smoothen the PEC and avoid honey comb. This aluminium ruler (2" x 4") should be 24' long: 2 new aluminium pipes of 12' should be joined together with a seamless joint and the assembly must be absolutely straight.
- Wet jute cloth should be laid only after 2 hours after casting.
- Care should be taken not to step on the fresh cast PEC.
- Car should be taken to protect the road against dog.
- Road should be cured for 1 week, several times per day, covered with jute cloth during that time.
- Jute cloth would be removed after 1 week and the road exposed to sun cured several times per day for 3 days.

– Road would be opened 10 days after casting (1 week curing with jute cloth + 3 days curing under sun).
– Curing will go on for 2 more weeks, several times per day and exposed to sun without jute cloth. This will give a total of 24 days total for curing.
– 24 cylinder samples should be cast so as to test them (dry and wet compression tests) at different periods of time: after 2 weeks, after 1 month, after 6 months and 12 months

## 8.4 MATERIALS REQUIREMENT PER M² OF ROAD

The following table gives the material requirement per square metre of road with the new mix ratio. Note that these amounts will have to be checked once the new road will be done and the correspondent Excel file updated also.

| QUANTITIES OF MATERIALS PER M2 OF ROAD | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ITEM | MIX RATIO FOR WEARING COURSE | | SUB-COURSE | | WEARING COURSE | | TOTAL ROAD (DELIVERY) | |
| | | | Thickness (cm) | 10 | Thickness (cm) | 15 | Area ($m^2$) | 1 |
| | | | | | | | Length (m) | 1 |
| | Unit | Unit | Qty/road | Unit | Qty/road | Unit | Qty/road | Unit |
| Cement (~5.4 % = 25 Kg/mix) | 25 | Kg/mix | 0.41 | Bag | 0.28 | Bag | **0.69** | **Bag** |
| Lime (~5.4 % = 25 Kg/mix) | 25 | Kg/mix | 0.08 | Bag | 0.35 | Bag | **0.43** | **Bag** |
| Red soil raw laying curbs, Embankment | - | - | 0.279 | $m^3$ | - | - | **0.28** | **$m^3$** |
| Red Soil crushed | 75 | L/mix | 0 | $m^3$ | 0.042 | $m^3$ | **0.04** | **$m^3$** |
| Sieved sand 4mm or quarry dust 2mm | 25 | L/mix | 0 | $m^3$ | 0.014 | $m^3$ | **0.01** | **$m^3$** |
| Sieved sand 4mm or quarry dust 2mm | - | - | 0.024 | $m^3$ | - | - | **0.02** | **$m^3$** |
| Gravel Chips | 60 | L/mix | 0 | $m^3$ | 0.034 | $m^3$ | **0.03** | **$m^3$** |
| Gravel 1/2" | 50 | L/mix | 0.024 | $m^3$ | 0.028 | $m^3$ | **0.05** | **$m^3$** |
| Gravel 1" | 50 | L/mix | 0.024 | $m^3$ | 0.028 | $m^3$ | **0.05** | **$m^3$** |
| 1.5" aggregates | 50 | L/mix | 0 | $m^3$ | 0.028 | $m^3$ | **0.03** | **$m^3$** |
| 1.5" aggregates mixed | - | - | 0.165 | $m^3$ | - | - | **0.17** | **$m^3$** |
| Curbs 1m (PEC 1: 0.5: 2: 2: 2: 2) | - | - | 2 | Nos. | - | - | **2.00** | **Nos.** |
| Water for soaking sub course+casting | 56 | L/mix | 0.031 | $m^3$ | 0.031 | $m^3$ | **0.06** | **$m^3$** |
| Water curing | 150 | $L/m^2$ | 0 | $m^3$ | 0.150 | $m^3$ | **0.15** | **$m^3$** |

*Table 21: Material requirement per $m^2$ of road*

## 8.5 TEAM REQUIREMENT

The following table give the team details for casting the PEC. Note that this team is slightly different than the one used for doing the road at the Visitor's Centre.
The units for the following numbers of workers are "man/day".

| WORK | | WORKER | MASON | SUPERVISOR | OTHER SKILL |
|---|---|---|---|---|---|
| **Precasting curbs** | | 2 | 1 | 1 (¼ h./day) | - |
| **Site preparation** | | 9 | 1 | 1 | 0.25 JCB driver |
| **Excavation and levelling the road** | | 9 | 1 | 1 | 0.25 JCB driver |
| **Laying curbs** | | 4 | 2 | 1 | - |
| **Sub-Course and embankment** | | 12 | 2 | 1 | ~0.5 Bobcat driver, ~0.4 Roller driver |
| **Wearing Course** | **Mixing** | 8 | - | 1 | 1 Mixer operator, 2 Students |
| | **Casting** | 6 | 4 | 1 | 2 vibrator operator |
| | **Road surfacing** | 3 | - | | - |
| | **Curing** | 1 | - | 1 (½ h./day) | - |

*Table 22: Team detail for mixing and casting a new PEC road*

## 8.6 TOOL REQUIREMENT

The following table gives details for the tools required for the future PEC road. Note that this list has been modified from the one showed page 14.

| MACHINERY | |
|---|---|
| **Item** | **Nos.** |
| JCB (digging and site preparation) | 1 |
| Bobcat (levelling sub course & site preparation) | 1 |
| Concrete mixer 10/7 CFT (casting time) | 1 |
| Vibrator (casting time) | 3 |
| Fuel can for machines | 1 |
| 2 KVA generator | 1 |
| Extension cable 50 m | 1 |
| Heavy duty grinding machine + 2 stone disk | 1 |
| | |

| SPECIAL TOOLS | |
|---|---|
| **Item** | **Nos.** |
| Steel screed ruler with handles 10 x 5 cm x 7 m | 2 |
| Steel screed ruler with handles 10 x 5 cm x 5 m | 2 |
| Aluminium screed ruler 4" x 2" x 24' | 1 |
| Aluminium rule 4" x 2" x 12' | 1 |
| Aluminium rule 2" x 1" x 6' | 2 |
| Slump test set (cone, rod, scale, plywood 50x50) | 1 |
| Hose pipe | 80 m |
| Hose pipe carrier | 1 |
| Scale (300 Kg) | 1 |
| Wooden ramp (mixer & crusher) | 2 |
| Extra wooden ramp | 1 |
| Rubber boots | 8 |
| Protection goggle | 8 |
| Dust mask | 100 |
| Rubber gloves | 12 |
| Leather gloves | 8 |
| Road scraper with wire brushes | 2 |
| Split joint set (6 sheets 1m + 1 sheet 0.5 m) | 1 |
| Tarpaulin 15 x 15 m | 1 |
| Tarpaulin 18 x 14 m | 1 |
| Tarpaulin 12 x 8.5 m | 2 |
| Tarpaulin 9 x 9 m | 1 |
| 10 m chain with lock | 1 |
| 50 m tape (Plastic tape) | 1 |
| 50 m tape (steel tape) | 1 |
| 7.5 m tape | 2 |
| Thick rope (~1 cm ∅) | 50 m |
| Chalk line | 2 |
| First aid kit | 1 |
| Paper cutter with spare blades | 1 |
| Cylinders for casting samples (∅30.5 x 30 cm) | 6 |
| Marine plywood (casting samples) 1.2 x 1.2 m | 1 |
| | |
| | |

| HAND TOOLS | |
|---|---|
| **Item** | **Nos.** |
| Crow bar | 3 |
| Hoe | 10 |
| Shovel | 10 |
| Mason tool sets | 4 |
| Hard broom for floor | 4 |
| Large broom | 3 |
| Steel rake | 3 |
| Scraper (for SREF) | 2 |
| Roll of string line | 1 |
| ∅ 12 mm rod ~ 1 m | 12 |
| Sledge hammer | 1 |
| Tube level 30 m | 1 |
| Rammer 200 | 4 |
| Rammer 100 | 4 |
| Tools set (spanners, screw driver, etc.) | 1 |
| | |
| | |

| HANDLING & CONTAINERS | |
|---|---|
| **Item** | **Nos.** |
| Wheelbarrow flat | 2 |
| Wheelbarrow 50 L. | 5 |
| Wheelbarrow 75 L. | 2 |
| Wheelbarrow 100 L. | 2 |
| Wheelbarrow 200 L. | 2 |
| Plastic barrel 200 L. (1 near casting)<br>(2 mixing concrete + 1 engine mixer) | 4 |
| Plastic barrel 100 L.<br>(1 engine mixer + 1 near casting) | 2 |
| Pan | 10 |
| Mortar mixing pan (116 x 116) | 2 |
| Aluminium bucket 11L. | 6 |
| Aluminium bucket 15 L. | 6 |
| Plastic bucket 22 L. | 4 |
| Steel box 42 L. | 2 |
| Measuring cylinder 2 L. | 1 |
| Measuring cylinder 1 L. | 1 |
| Measuring cylinder 0.5 L. | 1 |
| Plastic can 35 l. with diesel | 1 |
| Drinking water can 25 L with tap | 2 |
| Stainless steel glass | 2 |
| Steel box 82 x 42 x 30 cm for small tools | 1 |
| | |
| | |
| | |
| | |

*Table 23: Tool requirement for new road*